The CERCular
Coastal Engineering Research Center

Vol CERC-96-1 March 1996

# Numerical Modeling of Storm-Induced Beach Erosion

by Randall A. Wise and S. Jarrell Smith

## Introduction

Beaches erode and accrete in response to varying waves and water levels in the nearshore zone. During storms, catastrophic beach and dune erosion can occur in a matter of hours, resulting in significant shoreline recession and damage to property and upland resources (Figure 1). Consequently, protection of upland infrastructure against storm erosion, flooding, and wave attack is a primary concern in the field of coastal engineering. Effective design of shore protection measures requires an understanding of and the capability to predict sediment transport processes that control beach response to storms. Numerical modeling of beach evolution is a powerful technique that can be applied to assist in project design. Numerical models provide a framework for predicting project response, objectively evaluating the effectiveness of design alternatives, and analyzing data to develop an understanding of coastal processes. The Storm-induced BEAch CHange (SBEACH) numerical model has been developed by the U.S. Army Corps of Engineers as an engineering tool for simulating beach profile evolution in response to storms.

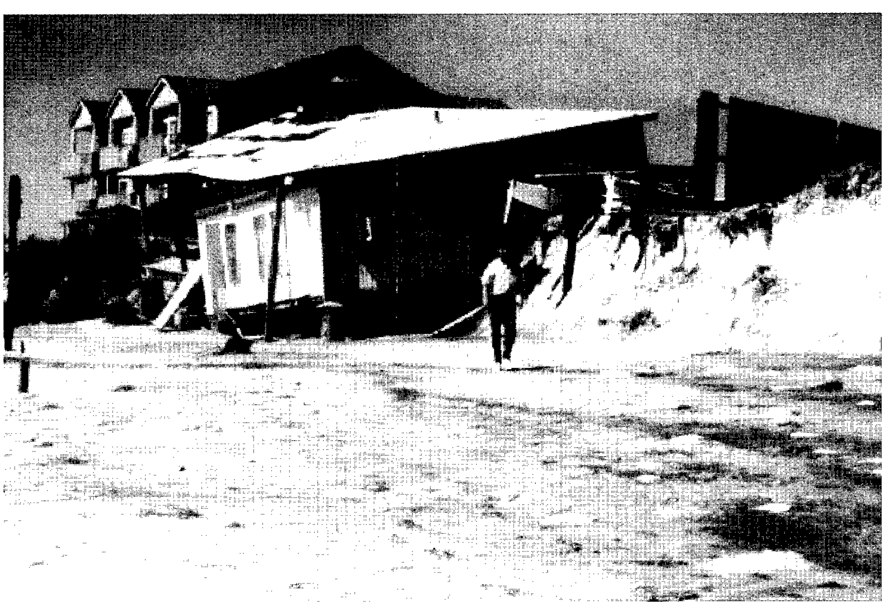


*Figure 1. Storm-induced beach erosion produced by Hurricane Opal, October 1995, Walton County, Florida*

## Overview of SBEACH Model

SBEACH is an empirically based numerical model for simulating two-dimensional cross-shore beach change. The model was initially formulated using data from prototype-scale laboratory experiments and has been further developed and verified with laboratory and field data. SBEACH calculates meso-scale beach profile change with emphasis on beach and dune erosion and bar formation and movement. The model is intended for predicting short-term profile response to storms. A fundamental assumption of the SBEACH model is that profile change is produced solely by cross-shore processes, resulting in a redistribution of sediment across the profile with no net gain or loss of material. Longshore processes are considered to be uniform and neglected in calculating profile change. This assumption is expected to be valid for short-term storm-induced profile response on open coasts away from tidal inlets and coastal structures. Detailed information on model development and application is provided in a series of technical and instruction reports (Larson and Kraus 1989; Larson, Kraus, and Byrnes 1990; Rosati et al. 1993; Wise, Smith, and Larson 1996). Recent model enhancements include a random wave model and refined sediment transport relationships to improve calculation of beach response under random waves, and an algorithm to simulate beach and dune erosion produced by overwash.

SBEACH requires data typically available in engineering studies to calculate beach profile response. For project applications, primary input to SBEACH includes time-histories of storm wave height and period (direction is optional) and water level; beach profile survey data; and median sediment grain size. Sampling intervals of input wave and water level time-histories usually range from 1 to 4 hr. Input required for model configuration includes parameters such as grid size, time-step, and calibration coefficients (default values are defined). Typical values of model grid size and time-step are 3 m and 5 min, respectively. The model operates through a graphical user interface which facilitates data input, model execution, and analysis of model results.

## Field Case Study - Dewey Beach, DE

On 10 December 1992, a northeaster impacted the Atlantic coast of Delaware producing substantial erosion. Beach response to the storm was captured at Dewey Beach through data collected by the U.S. Army Engineer District, Philadelphia, as part of a project feasibility study. Pre-storm profiles were measured on 29 October 1992 and post-storm surveys were performed shortly after the storm on 18 December 1992. Pre- and post-storm measurements were available for seven profile lines. Wave conditions during the storm were recorded by a wave gauge located at a depth of approximately 9 m off the coast of Dewey Beach. Tide information was available from a nearby tide gauge located at Lewes, DE. The storm had a peak significant wave height of 4 m, a peak water level of approximately 2 m above National Geodetic Vertical Datum (NGVD), and a duration of 4 days. The measured time histories of wave and water level data provided information needed to model profile response to the storm.

The SBEACH model was applied to each of the seven profile lines at Dewey Beach using default values of the model calibration parameters. A sediment grain size of 0.33 mm was employed in all model simulations. An example of model simulation results is shown in Figure 2 for profile 140. The dashed line represents the pre-storm measured profile, which was input as the initial profile for model calculations; the heavy solid line represents the post-storm measured profile; and the light solid line shows the eroded profile as calculated by SBEACH. Both the measured and calculated profiles indicate extensive erosion of the berm, moderate erosion of the dune, and deposition of sediment in the offshore. The calculation shows more erosion of the nearshore profile below NGVD than observed in the measurements; however, it is likely that some material deposited in the bar was returned to the nearshore through recovery processes occurring during the several days between the end of the storm and the time of the post-storm surveys. Although post-storm recovery was not modeled by SBEACH, overall the model performed well in reproducing measured erosion of the upper profile.

Accurate simulation of profile response at the foreshore and dune is important in engineering applications, where model estimates of erosion are used to determine effects of storms on structures and property adjacent to the shoreline. To quantify the accuracy of SBEACH in simulating response of the upper profile, measures of performance were selected based on types of information that a field engineer requires in the assessment of storm damage. Performance measures include volume loss above the profile datum, recession of a specified beach contour, and storm intrusion represented by the landward limit of a specified amount of vertical erosion (Figure 3). These quantities were calculated for each of the seven profile lines to compare measured and simulated profile response.

Figure 4 shows measured and predicted volumes of erosion above NGVD for the profile lines at Dewey Beach. Volume change calculations identify how well a model simulates erosion of the subaerial beach, which is important in estimating volume requirements for beach fill operations. For the storm at Dewey Beach, measured volume loss

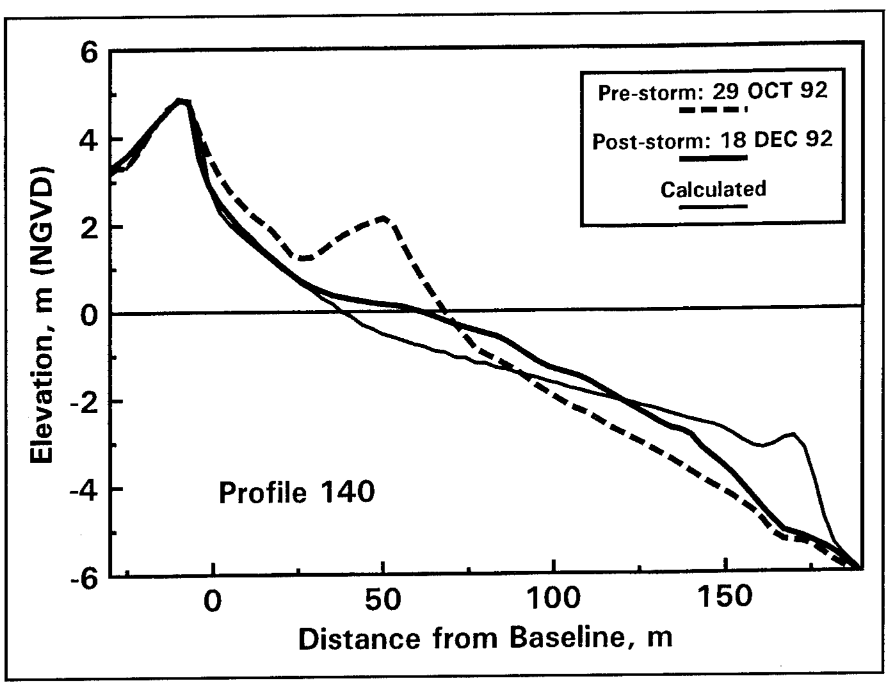



*Figure 2. Calculation of beach erosion, December 10, 1992 storm, Dewey Beach, Delaware*

above NGVD averaged approximately 70 cu m/m. SBEACH reproduced the measured volume loss reasonably well for each profile. The maximum deviation between predicted and measured values is 11 cu m/m at profile 240.

Figure 5 displays measured and predicted values of recession of the 1.5-m NGVD contour. Comparing horizontal recession of a specified contour indicates how well a model simulates erosion of a given feature (such as a dune or berm) on the beach profile. Contour recession also provides information on loss of beach width resulting from a storm. For the Dewey Beach data, the 1.5-m contour corresponds to the elevation of the upper berm prior to the storm. Figure 5 shows that model predictions are within a few meters of the measured values of recession at all profile lines. Trends observed in the measured values are well reproduced by the model.

Figure 6 shows measured and predicted values of storm intrusion defined by distance from the profile datum to a vertical erosion of 0.3 m. Storm intrusion is often employed in beach fill design to quantify the landward extent of potential structural damage caused by erosion and undermining. Measured storm intrusion averaged approximately 60 m at Dewey Beach. Model predictions closely match the measured values at all profile lines.

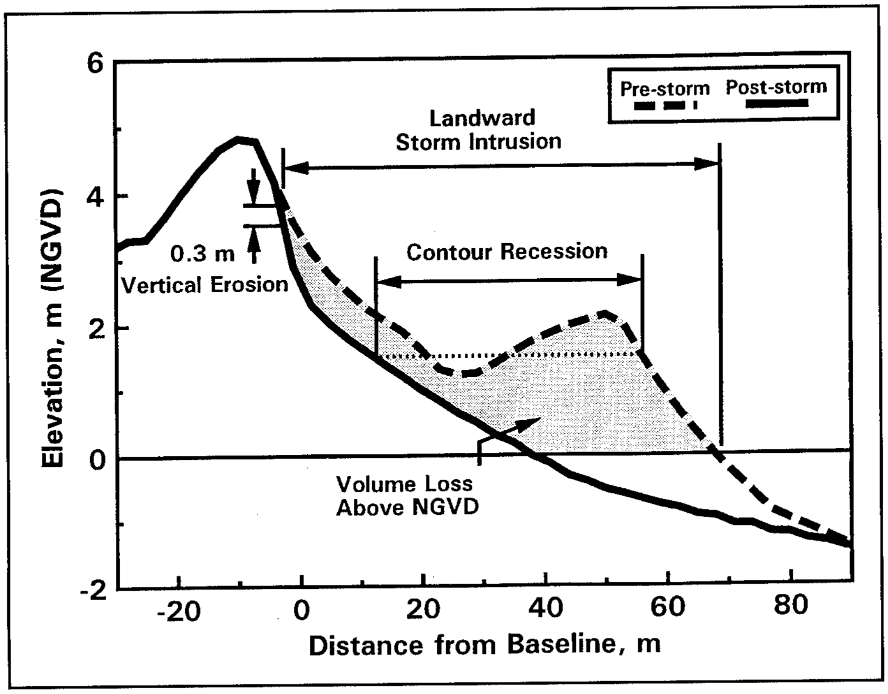



*Figure 3. Measures of erosion at the foreshore*

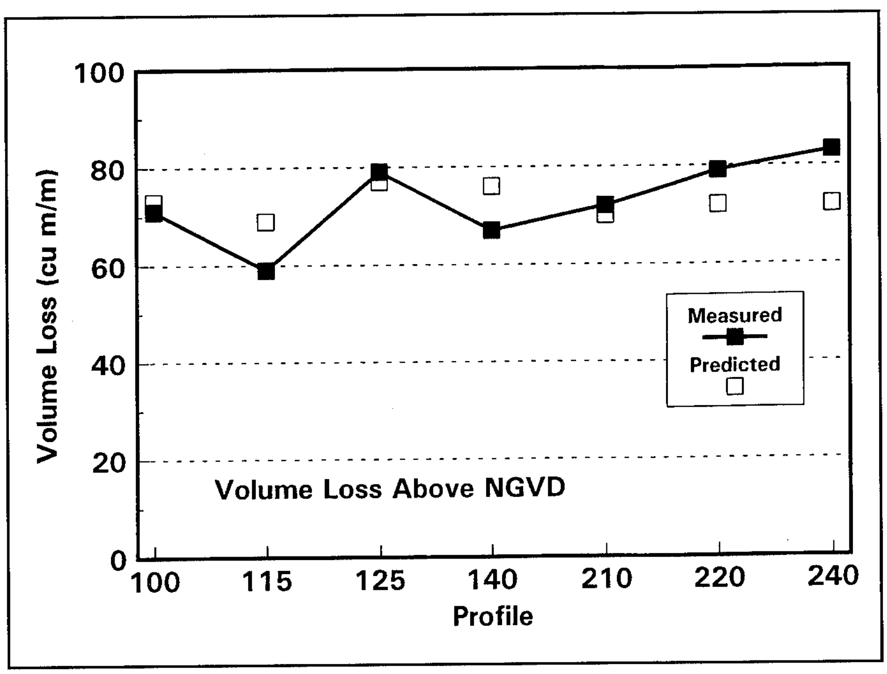



*Figure 4. Comparison of measured and predicted volume change, Dewey Beach*

## Summary

The SBEACH model has been developed as an engineering tool for predicting beach profile response to storms. Application of the model with profile and storm data from Dewey Beach, DE, demonstrates capabilities of the model in simulating storm-induced beach erosion. The model performed well in reproducing parameters which quantify foreshore and dune response. Additional field case studies involving high-quality data from Ocean City, MD; Manasquan and Point Pleasant Beach, NJ; Rehoboth Beach, DE; and Debidue and Myrtle Beaches, SC are presented by Wise, Smith, and Larson (1996). The field case studies investigate simulation accuracy using default versus calibrated model parameters, and quantify model performance based on measures of erosion at the dune and foreshore. Wise, Smith, and Larson (1996) also present an extensive evaluation of SBEACH using data from the SUPERTANK laboratory project (Kraus and Smith 1994) involving various wave conditions and beach profile configurations. Areas of future model development include simulation of profile change over non-erodible hard bottoms, representation of variable sediment grain size across the profile, and improved calculation of sediment transport in the offshore zone to describe movement of dredged material placed in submerged mounds.

## References


Kraus, N. C., and Smith, J. M. (1994). "SUPERTANK Laboratory Data Collection Project," Technical Report CERC-94-3, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Larson, M., and Kraus, N. C. (1989). "SBEACH: Numerical model for simulating storm-induced beach change; Report 1, Empirical foundation and model development," Technical Report CERC-89-9, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Larson, M., Kraus, N. C., and Byrnes, M. R. (1990). "SBEACH: Numerical model for simulating storm-induced beach change; Report 2, Numerical formulation and model tests," Technical Report CERC-89-9, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Rosati, J. D., Wise, R. A., Kraus, N. C., and Larson, M. (1993). "SBEACH: Numerical model for simulating storm-induced beach change; Report 3, User's manual," Instruction Report CERC-93-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Wise, R. A., Smith, S. J., and Larson, M. (1996). "SBEACH: Numerical model for simulating storm-induced beach change; Report 4, Cross-shore transport under random waves and model validation with SUPERTANK and field data," Technical Report CERC-89-9, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS (in publication).

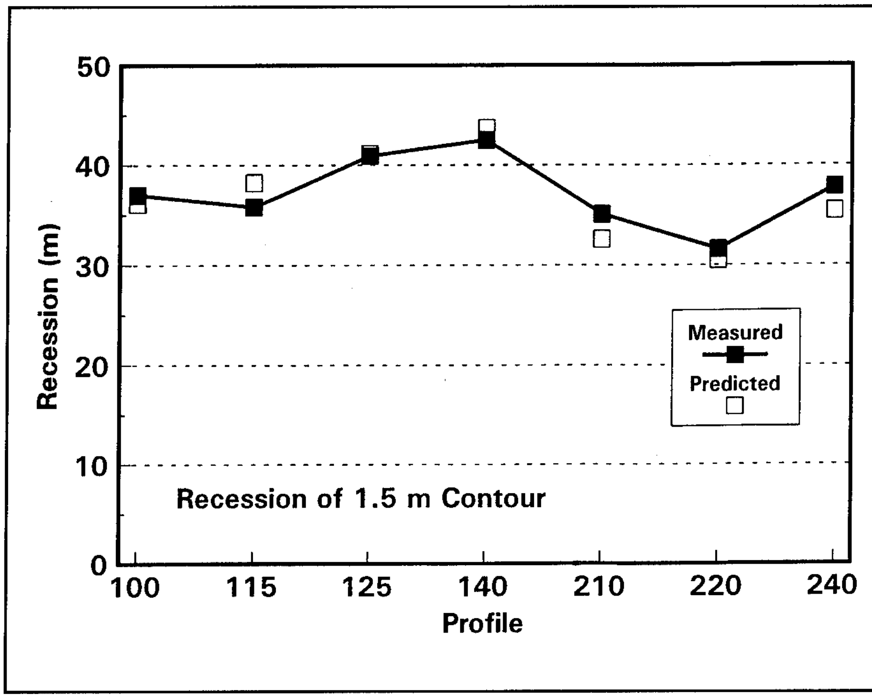




*Figure 5. Comparison of measured and predicted contour recession, Dewey Beach*

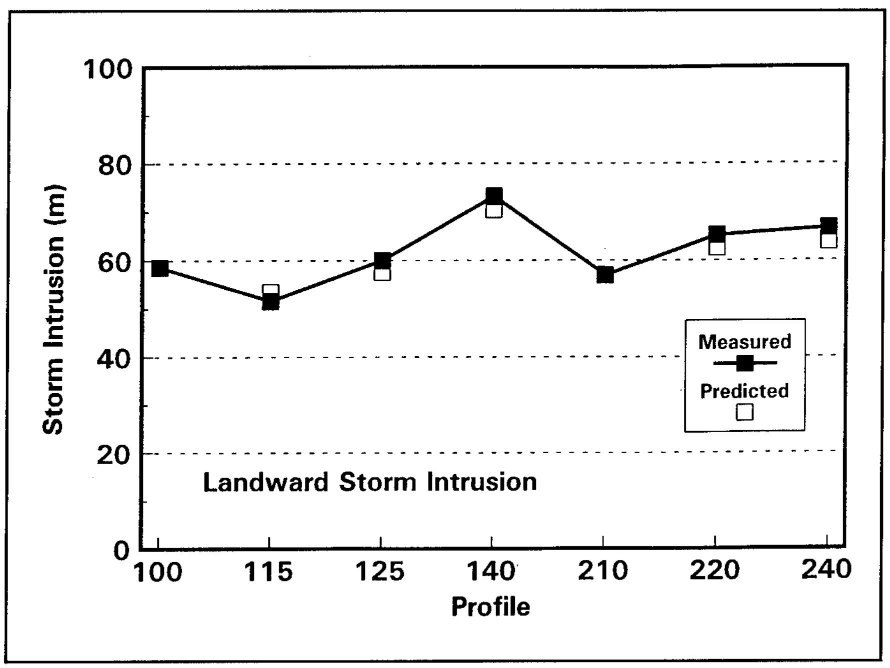



*Figure 6. Comparison of measured and predicted storm intrusion, Dewey Beach*

# Publications of Interest

The following publications are available from the sources indicated. They are not available from CERC.

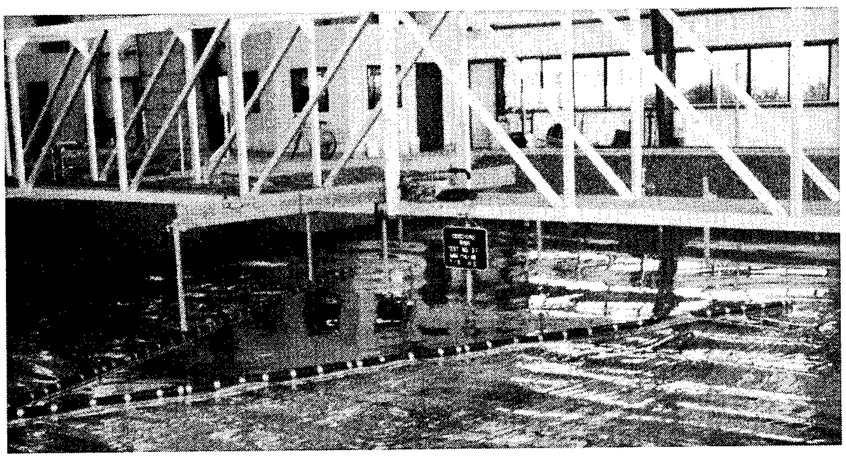
*North Carolina's Hurricane History,* 202 pages, hard cover $34.95, paperback $16.95. Available from the University of North Carolina Press, PO Box 2288, Chapel Hill, NC, 27515-2288, USA.

*Quantitative Skill Assessment for Coastal Ocean Models,* 1995, 510 pages, hardbound $70 (AGU members $49), and *Three-Dimensional Coastal Ocean Models,* 1987, 208 pages, hardbound $30 (AGU members $21), MasterCard, Visa, and American Express accepted, $3 per book additional for invoiced orders, orders under $50 must be prepaid. Available from the American Geophysical Union, 800-966-2481, 202-462-6900, or in Europe 49-5556-1440; FAX 202-328-0566 or in Europe 49-5556-4709; E-mail: cust_ser@kosmos.agu.org or in Europe agu@linax1.dnet.gwdg.de

*Criteria for Movements of Moored Ships in Harbours - A Practical Guide,* 1995, 35 pages, price not listed. Available from the Permanent International Association of Navigation Congresses, General Secretariat, WTC- Tour 3 -26$^{e}$ etage, Boulevard Simon Bolivar 30, B-1210 Brussels, BELGIUM.

*Coastal Engineering Technical Notes,* over 180 notes of varying length, $60 (price includes future updates), payment required in advance in U.S. dollars, checks should be made payable to the United States Treasury. Copies are available from U.S. Army Engineer Waterways Experiment Station, ATTN: Disbursing Office, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199.

*Shore Protection Manual,* 4th ed., 1984, over 1200 pages, $77, MasterCard and Visa accepted. Copies are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC, 20402, or from U.S. Government bookstores located in major cities.



***A design concept for a rapidly installed floating breakwater system was recently tested by CERC at the O.H. Hinsdale Wave Research Laboratory at Oregon State University. Field tests of prototype scale units are scheduled***

## CERB to Meet

The next meeting of the Coastal Engineering Research Board (CERB) will be hosted by the South Pacific Division and the Los Angeles District on 11-12 June 1996 in San Diego, California. The CERB was established by Congress to advise the Chief of Engineers on Coastal Engineering matters. The theme for this meeting is "The Direction of Coastal Engineering in the Corps and the Resulting Impact on R&D." The Board will hear from a wide spectrum of interests including academia, ports, private consultants, military, and the legal community. The meetings are open to the public. Point of contact is Ms. Sharon L. Hanks, (601) 634-2004.

# CERC Publications

## Book Chapters

The following book chapter was co-authored by CERC engineers and scientists.

Briggs, M. J., Synolakis, C. E., Harkins, G. S., and Hughes, S. A. (1995). "Large scale three-dimensional laboratory measurements of tsunami inundation." *Tsunami: Progress in prediction, disaster prevention and warning.* Y. Tsuchiya and N. Shuto, eds., Kluwer Academic Publishers.

## Journals

Listed below are journal papers published in 1995 that were authored or co-authored by CERC personnel. This listing provides sources of information about CERC activities that are readily available in open literature.

Briggs, M. J., Synolakis, C. E., Harkins, G. S., and Green, D. R. (1995). "Laboratory experiments of tsunami runup on a circular island," *Journal of Pure and Applied Geophysics (PAGEOPH)* 144(3/4).

Briggs, M. J., Thompson, E. F., and Vincent, C. L. (1995). "Wave diffraction around breakwater," *Journal of Waterway, Port, Coastal, and Ocean Engineering* 121(1).

Camfield, F. E., and Holmes, C. M. (1995). "Monitoring completed coastal projects," *Journal of Performance of Constructed Facilities* 9(3).

Frasier, S. J., Liu, Y., Moller, D., McIntosh, R. E., and Long, C. (1995). "Directional ocean wave measurements in a coastal setting using a focused array imaging radar." *Transactions on geoscience and remote sensing* 33(2).

Hales, L. (1995). "Accomplishments of the Corps of Engineers Dredging Research Program," *Journal of Coastal Research* 11(1).

Hammack, J., McCallister, D., Scheffner, N., and Segur, H. (1995). "Two-dimensional periodic waves in shallow water; Part 2, Asymmetric waves," *Journal of Fluid Mechanics* 285.

Harkins, G. S. (1995). "Effectiveness of wave absorbers at Barbers Point Harbor," *Bulletin, Permanent International Association of Navigation Congresses* 86.

Houston, J. R. (1995). "Beach nourishment," *Shore & Beach* 63(1).

Hughes, S. A., and Fowler, J. E. (1995). "Estimating wave-induced kinematics at sloping structures," *Journal of Waterway, Port, Coastal, and Ocean Engineering* 121(4).

Jackson, F. E., and Jensen, R. E. (1995). "Wave field response to frontal passages during SWADE," *Journal of Coastal Research* 11(1).

Lee, G.-H., Nicholls, R. J., Birkemeier, W. A., and Leatherman, S. P. (1995). "A conceptual fair-weather-storm model of beach nearshore profile evolution at Duck, North Carolina, U.S.A.," *Journal of Coastal Research* 11(4).

Leenknecht, D. A., Sherlock, A. R., and Szuwalski, A. (1995). "Automated tools for coastal engineering," *Journal of Coastal Research* 11(4).

Lillycrop, W. J. (1995). "Surveying with SHOALS," *Military Engineer* 87(572).

Liu, P. L.-F., Cho, Y.-S., Briggs, M. J., Kanoglu, U., and Synolakis, C. E. (1995). "Runup of solitary waves on a circular island," *Journal of Fluid Mechanics* 302.

Long, C. E., and Sallenger, A. H., Jr. (1995). "Experiment at Duck, N.C. beach explores nearshore processes," *EOS* 76(49).

Melby, J. A., and Turk, G. F. (1995). "CORE-LOC: Optimized concrete armor units," *Bulletin, Permanent International Association of Navigation Congresses* 87.

Pollock, C. B. (1995). "Helicopter-borne nearshore survey system, a valuable tool in difficult survey areas," *Journal of Coastal Research* 11(3).

Sudar, R. A., Pope, J., Hillyer, T., and Crumm, J. "Shore protection projects of the U.S. Army Corps of Engineers," *Shore & Beach* 63(2).

Thevenot, M. M., and Kraus, N. C. (1995). "Longshore sand waves at Southampton Beach, New York: Observation and numerical simulation of their movement," *Marine Geology* 126.

Thompson, E. F., Ward, D. L., Domurat, G. W., Pirie, D. M., and Oliver, J. G. (1995). "General design process for coastal projects," *Shore & Beach* 63(1).

Thompson, E. F., and Hadley, L. L. (1995). "Numerical modeling of harbor response to waves," *Journal of Coastal Research* 11(3).

Tracy, B. A., and Brandon, W. A. (1995). "A combined wave and surge hindcast for the coast of Florida during Hurricane Andrew," *Journal of Coastal Research*, Special Issue No. 21.

The following journal papers were prepared under contracts issued by CERC.

Larson, M. (1995). "Model for decay of random waves in surf zone," *Journal of Waterway, Port, Coastal, and Ocean Engineering* 121(1).

Moritz, H. R., and Randall, R. E. (1995). "Simulating dredged-material placement at open-water disposal sites," *Journal of Waterway, Port, Coastal, and Ocean Engineering* 121(1).

# Calendar of Coastal Events of Interest

A more complete calendar, updated weekly, will be found on the World Wide Web at http://bigfoot.cerc.wes.army.mil/event_cal.html.

| | |
|---|---|
| May 26 - 30, 1996 | **39th Conference on Great Lakes Research**, Erindale College, Univ. of Toronto, Canada, POC: W. Gary Sprules, (905) 828-3987, E-mail: gsprules@cyclops.erin.utoronto.ca |
| Jun 11 - 14, 1996 | **Western Dredging Association, WEDA XVII, and 29th Annual Dredging Seminar,** New Orleans, LA, POC: Dr. Robert E. Randall, (409) 845-4568, FAX (409) 862-1542 or 845-6156 |
| Jun 17 - 22, 1996 | **Seventh Pacific Congress on Marine Science and Technology, PACON 96,** Ilikai Hotel, Honolulu, HI, FAX (808) 956-2580, E-mail: pacon@wiliki.eng.hawaii.edu |
| Jun 19 - 22, 1996 | **1996 World Congress on Coastal and Marine Tourism,** Ilikai Hotel, Honolulu, HI, E-mail: auyongj@ccmail.orst.edu |
| Jul 14 - 17, 1996 | **Coastal Society 15th International Conference,** Seattle, WA, POC: Megan D. Bailiff, E-mail: mbailiff@u.washington.edu |
| Jul 21 - 26, 1996 | **Hazards '96,** Toronto, Canada, POC: M. I. El-Sabh, FAX (418) 724-1842, E-mail: mohammed_el_sabh@uqar.uquebec.ca |
| Jul 29 - Aug 2, 1996 | **Pan Pacific Hazards '96,** Vancouver, British Columbia, Canada, FAX (604)-822-6164, E-Mail: dprc@unixg.ubc.ca |
| Aug 7 - 9, 1996 | **Coastal Environment '96,** Rio de Janeiro, Brazil, E-mail: cmi@ib.rl.ac.uk |
| Aug 12 - 17, 1996 | **Coastal Zone Canada '96,** Rimouski, Quebec, Canada, POC: M. I. El-Sabh, FAX (418) 724-1842, E-mail: mohammed_el_sabh@uqar.uquebec.ca |
| Aug 13 - 16, 1996 | **PORSEC '96, Pacific Ocean Remote Sensing Conference,** Victoria Conference Centre, Victoria, BC, Canada, FAX (604)-363-6479, ATTN: PORSEC '96, E-mail: porsec96@ios.bc.ca |
| Aug 26 - 29, 1996 | **10th Congress of Asia and Pacific Division,** IAHR, Langkawi Island, Malaysia, POC: Say-Chong Lee, E-mail: iphk@moa.my |
| Sep 1 - 6, 1996 | **25th International Conference on Coastal Engineering,** Peabody Hotel, Orlando, FL, POC: ICCE '96, (512) 994-2376, FAX (512) 994-2715, E-mail: icce96@cbi.tamucc.edu |
| Sep 16 - 19, 1996 | **Littoral '96,** Portsmouth, United Kingdom, E-mail: edwardss@envf.port.ac.uk |
| Sep 24 - 29, 1996 | **Eastern Pacific Oceanic Conference,** Stanford, CA, FAX (503) 737-2064, E-mail: kosro@oce.orst.edu |
| Oct 12 - 16, 1996 | **American Shore and Beach Preservation Assoc. Annual Conference,** Chicago, IL |
| Oct 22 - 25, 1996 | **Ocean Optics XIII,** Halifax, Nova Scotia, Canada, POC: Trudy D. Lewus, E-mail: trudy@satlantic.com |
| Dec 2 - 6, 1996 | **Natural and Technological Coastal Hazards,** Tirupati, AP, India, POC: Dr. C. Rajasekara Murthy, FAX (905) 336-4989/6230 |

**US Army Corps of Engineers**
Waterways Experiment Station

## The Corps' Coastal Vision Statement

**We will, as the National Coastal Engineer:**

- **Continue our leadership in the protection, optimization, and enhancement of the Nation's coastal zone resources.**
- **Increase our contribution to the Nation's economy, quality of life, public safety, and environmental stewardship.**

The **CERCular**

**Coastal Engineering Research Center**

This bulletin is published in accordance with AR 25-30 as an information dissemination function of the U.S. Army Engineer Waterways Experiment Station. The publication is part of the technology transfer mission of CERC under PL 79-166. Results from ongoing research programs will be presented. Special emphasis will be placed on articles relating to application of research results or technology to specific project needs. Additional information is provided on the CERC Homepage at:

http://bigfoot.cerc.wes.army.mil/CERC_homepage.html

Contributions of pertinent information are solicited from all sources and will be considered for publication. Communications are welcomed and should be addressed to the Coastal Engineering Research Center, ATTN: Dr. Fred E. Camfield, U.S. Army Engineer Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199, or call (601) 634-2012, FAX (601) 634-3433, Internet: f.camfield@cerc.wes.army.mil

Robert W. Whalin

ROBERT W. WHALIN, PhD, PE
Director, WES

PRINTED ON RECYCLED PAPER